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Simulated Influence of Postweaning Production System on Performance of Different Biological Types of Cattle: III. Biological Efficiency

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ABSTRACT: Methods were developed and incorporated into a previously published computer model to predict ME intake and calculate biological efficiencies in terms of grams of empty BW (EBW) and fat-free matter (FFM) gained/megacalorie of ME consumed from weaning to slaughter. Efficiencies were calculated for steers from F_1 crosses of 16 sire breeds (Hereford, Angus, Jersey, South Devon, Limousin, Simmental, Charolais, Red Poll, Brown Swiss, Gelbvieh, Maine Anjou, Chianina, Brahman, Sahiwal, Pinzgauer, and Tarentaise) mated to Hereford and Angus dams, grown under nine backgrounding systems, finished at either a low (1.0 kg) or high (1.36 kg) ADG, and slaughtered at 300 kg carcass weight, small or greater degree of marbling, and 28% carcass fat. Backgrounding systems were high ADG (.9 kg) for 111, 167, or 222 d, medium ADG (.5 kg) for 200, 300, or 400 d, and low ADG (.25 kg) for 300 or 400 d, and 0 d backgrounding. The high ADG finishing system was more biologically efficient than the low ADG finishing system, and generally backgrounding systems were less biologically efficient than direct finishing after weaning (0 d backgrounding). Large-framed breeds were more efficient at the constant carcass weight and carcass fatness end point, and breeds that achieved the marbling end point at low levels of carcass fatness were more efficient at this end point. Some small-framed breeds gained EBW more efficiently but gained FFM less efficiently than some of the large-framed breeds. Variation in efficiency between genotypes was greatest with 0 d backgrounding and decreased in the other backgrounding systems.

Key Words: Carcass Composition, Computer Simulation

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Introduction

Efficiency of a biological production system is a function of the input-output relationships within the system. These relationships result from the underlying biological processes that transform inputs into outputs. Computer models that are designed to simulate production systems use mathematical equations to represent these biological processes. One common feature of these models is that they are input-driven, and they generate outputs appropriate to the biological processes that they represent. One example is a model that represents the biological processes responsible for the partitioning of nutrients into fat-free matter (**FFM**) and fat in growing cattle (Keele et al., 1992). This model uses rate of empty body weight (**EBW**) gain as an input and produces as output the body composition of the cattle at slaughter. This feature makes these models appropriate to study the efficiency with which inputs are transformed into outputs in different cattle production systems. In this study computer models were used to characterize the biological efficiency of different biological types of cattle when grown and finished under different postweaning production systems and slaughtered at different marketing end points.

Materials and Methods

Background

Growth and body composition of 17 biological types of steers grown under 18 postweaning production systems were simulated from birth to slaughter using a composition of gain model developed by Keele et al. (1992). Steers were produced from matings of Hereford, Angus, Jersey, South Devon, Limousin, Simmental, Charolais, Red Poll, Brown Swiss, Gelbvieh, Maine Anjou, Chianina, Brahman, Sahiwal, Pinzgauer, and Tarentaise sires to Hereford and

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Angus dams in the first three cycles of the Germ Plasm Evaluation (**GPE**) program at the Roman L. Hruska U.S. Meat Animal Research Center. Two breed parameters used in the composition of gain model were estimated from data on these steers and on cows of the same breed composition (Williams et al., 1995a).

Postweaning production systems simulated were nine backgrounding systems (Table 1) and two finishing systems. These backgrounding and finishing systems and BW and EBW growth rates used in these systems were previously described by Williams et al. (1995b). For each biological type of steer × postweaning production system combination, three runs were made to simulate the following three slaughter end points: 1) 300 kg carcass weight, 2) 28% carcass fat, and 3) small or greater degree of marbling. These slaughter end points and methods used to obtain carcass weight, carcass fat percentage, and degree of marbling from predicted EBW and composition were discussed by Williams et al. (1995b).

Table 1. Description of backgrounding systems[a] that were simulated

System	Days back-grounded	Backgrounding ADG, kg	Weight gain, kg
1	400	.5	200
2	222	.9	200
3	300	.5	150
4	167	.9	150
5	400	.25	100
6	200	.5	100
7	111	.9	100
8	300	.25	75
9	0	—	—

[a]All steers were weaned at 210 d of age, after which they were backgrounded in Systems 1 through 8, or put directly on a finishing diet in System 9.

Biological Efficiency

The term biological efficiency as used in this study is defined as an output:input ratio; hence, high values are representative of high efficiencies. Input was cumulative intake of ME in megacalories from weaning to slaughter, and efficiencies were calculated for two measures of output, 1) EBW gain from weaning to slaughter and 2) FFM gain from weaning to slaughter. Gain in FFM was obtained from the composition of gain model. A more appropriate estimate of biological efficiency would be to use boneless closely trimmed retail product as the measure of output, but there were no data to predict this at weaning. We assumed that FFM would be highly correlated with boneless closely trimmed retail product.

Prediction of Metabolizable Energy Intake

Predicted ME intake (**MEI**) cannot be obtained directly with the composition of gain model because it uses rate of EBW gain to represent differences in levels of nutrition. For growing cattle, MEI is the sum of ME used for maintenance (**MEM**) and ME used for gain (**MEP**). Therefore, a method of estimating MEP needs to be developed, and MEM for each biological type of steer needs to be estimated.

Estimation of Metabolizable Energy used for Gain. The composition of gain model used in this study predicts composition of EBW gain on a daily basis in terms of fat and FFM, and this information was used to obtain daily estimates of RE (**dRE**). Daily estimates of MEP (**dMEP**) were obtained by dividing dRE by the efficiency of utilization of ME for gain (**kf**). These procedures are summarized with the following equations:

dEBW = daily gain of EBW (kg, input to model),
dFFM = daily gain of fat free matter (kg, predicted with model),
dFAT = dEBW − dFFM (kg, daily gain of fat),
dPRO = dFFM ∗ .243 (kg, daily gain of protein),
dRE = dPRO ∗ 5.72 + dFAT ∗ 9.5,
kf = $1.42 - .174 * \mathrm{MED} + .0122 * \mathrm{MED}^2 - 1.65/\mathrm{MED}$,
MED = concentration of ME in diet (Mcal/kg of DM), and
dMEP = RE/kf (Mcal, amount of daily ME intake used for gain).

The constant .243 used to calculate daily gain of protein is the fraction of protein in FFM. This fraction was estimated with data from Fox and Black (1984) and it was not much different from estimates obtained for 14-mo-old Hereford, Charolais, and Simmental heifers, which were .247, .243, and .244, respectively (Buckley, 1985). Gross energy values of protein and fat (5.72 and 9.5) were obtained from Nehring and Haenlein (1973). The equation to calculate kf was taken from Garrett (1980), and the following values for MED were used in this equation. For high and low finishing ADG, values of 3.0 and 2.7, respectively, were used for MED. Smith et al. (1977) obtained an ADG of .93 kg for both small- and large-framed steers on a diet with a MED of 2.4, and this value was used for backgrounding at an ADG .9 kg. Other data from Smith et al. (1977) showed that small- and large-framed steers on a diet with a MED of 2.18 had an ADG of .67 kg. Linearly extrapolating the growth data with 2.4 and 2.18 MED resulted in MED values of 2.04 and 1.82 for systems in which the backgrounding ADG were .5 and .25 kg, respectively.

Estimation of Metabolizable Energy Used for Maintenance. The above system of equations provides an estimate of dMEP, and the next piece of information needed to predict daily MEI (**dMEI**) is an estimate of MEM. The following procedures were used to obtain an estimate of MEM for each biological type of steer. Breed-specific equations obtained from growth and MEI data of steers in the first three cycles of the GPE program (Smith et al., 1976b; Cundiff et al., 1981, 1984) were used to simulate growth and body composition with the composition of gain model and simulate dMEI from weaning to slaughter. Daily rates of change in empty body composition predicted with the model were used to calculate dRE, and values for dMEP were calculated from estimates of dRE and kf as previously discussed (MED values of the finishing diets were used to calculate kf). Estimates of daily ME used for maintenance (**dMEM**) were calculated as the difference between dMEI and dMEP, and these values were accumulated over the finishing period to obtain total ME used for maintenance (**TMEM**). Daily maintenance requirements in terms of megacalories of ME/kilogram of metabolic body size (**dMEM75**) were calculated with the following equation:

$$\mathrm{dMEM75} = \mathrm{TMEM} \;/ \sum_{X=1}^{X=f} (b_0 + b_1X + b_2X^2)^{.75},$$

where X is the number of days on feed, starting at d 1 and ending on day f, and b_0, b_1, and b_2 are breed-specific coefficients obtained from linear and quadratic regression of BW on days on feed (Smith et al., 1976b; Cundiff et al., 1981, 1984).

Restrictions

The possibility exists that for all production system by biological type of steer combinations the slaughter end points of 300-kg carcass weight, 28% carcass fat, or marbling score of 11 or greater may not be achieved within other marketing constraints on age at slaughter, carcass weight, and consumer acceptability. Therefore, other restrictions were placed on the system to satisfy these constraints. The first restriction was that steers had to be on feed for 56 d or more for a particular production system to be considered acceptable. This minimum period on feed was obtained from Miller et al. (1987), who found a significant increase in tenderness after a grain-finishing period of 56 vs 0 d, and no significant improvement with grain-finishing periods longer than 56 d. The second restriction was that steers had to be marketed at 28 mo of age or less. This restriction was aimed at satisfying the present marketing quality grade standards. The third restriction was that the weight of carcasses had to fall within the range of 250 to 408 kg, because carcasses outside this weight range are discounted. Production systems in which the desired slaughter end points were achieved within these restrictions will be referred to as feasible production systems.

Evaluation

Estimates of maintenance requirements of steers in Cycles I, II, and III of the GPE program were calculated from observed values of dMEI and estimates of dMEP obtained from daily gains of fat and FFM using the composition of gain model. This method to predict dMEP represents an extension of the composition of gain model in that predictions of dRE with this model are used along with information on MED to calculate dMEP. This method was evaluated by comparing estimates of maintenance requirements predicted with the model to estimates calculated in four experiments. Estimates of dMEI used to calculate biological efficiencies were obtained as the sum of estimated maintenance requirements and dMEP. This methodology was evaluated by comparing simulated and observed biological efficiencies (BW gain/megacalorie of ME) of steers in experiments by Dikeman et al. (1985a,b). In simulating these experiments, the published growth rates and ME densities of the diets were used.

Results and Discussion

Evaluation

Estimates of daily maintenance requirements in terms of kilocalories of ME/kilogram of $BW^{.75}$ (dMEM75) are given in Table 2 for each of the 17 biological types of steers. These estimates ranged from 131 for Angus steers to 178 for Chianina crossbred steers. Simulated estimates for crossbred steers from Red Poll, Brown Swiss, Gelbvieh, and Chianina sires were similar to observed estimates obtained from experimental data (Ferrell and Jenkins, 1985) for mature, pregnant, and lactating 8- or 9-yr-old cows of the same breeds, but were different for Maine Anjou-sired steers. Simulated estimates for steers sired by Limousin, Charolais, Simmental, and Chianina bulls ranked the same as observed estimates from Exp. 2 of Andersen (1980) for crossbred bulls of the same sire breeds. Simulated estimates also ranked the same with those calculated by Montaño-Bermudez and Nielsen (1990) for crossbred steers from Hereford and Red Poll sires. Observed estimates from Exp. 3 of Andersen (1980) for steers sired by South Devon, Charolais, Brown Swiss, and Gelbvieh bulls showed a different ranking compared with the simulated estimates for the same sire breeds. The estimates reported in Table 2 for the 17 biological types of steers were used in calculating dMEI according to procedures previously discussed.

Observed and simulated biological efficiencies (grams of BW gained/megacalorie of ME consumed) for the experiments of Dikeman et al. (1985a,b) are shown in Table 3. For the experiment of Dikeman et al. (1985a) simulated biological efficiencies of the accelerated systems decreased as slaughter weight

Table 2. Estimates of maintenance requirements (kcal of ME/kg of $BW^{.75}$) for steers in Cycles I, II, and III of the GPE program

Biological type[a]	Maintenance requirements: Estimated[b]	Ferrell and Jenkins (1985)[c]	Anderson (1980)[d] Exp. 2	Anderson (1980)[d] Exp. 3
Hereford	133	—	—	—
Angus	131	—	—	—
Hereford × Angus	139	151	—	—
Jersey ×	141	—	—	—
South Devon ×	145	—	—	129
Limousin ×	147	—	146	—
Charolais ×	150	—	157	136
Simmental ×	161	—	164	—
Red Poll ×	158	157	—	—
Brown Swiss ×	161	156	—	131
Gelbvieh ×	156	158	—	131
Maine Anjou ×	160	146	—	—
Chianina ×	178	174	169	—
Brahman ×	158	—	—	—
Sahiwal ×	161	—	—	—
Pinzgauer ×	148	—	—	—
Tarentaise ×	155	—	—	—

[a]Jersey × = 1/2 (Jersey × Hereford + Jersey × Angus), etc.
[b]Estimate for Hereford × Angus is an average value over Cycles I, II, and III. Estimates for other biological types were adjusted within cycle by the deviation of Hereford × Angus from the average value for Hereford × Angus.
[c]Estimates are for pregnant, lactating, 8- or 9-yr-old cows.
[d]An efficiency factor of .66 was used to convert NE to ME requirements.

increased; except for the accelerated system with 178 d on feed, a similar trend was seen in the observed data. Other data (Melton and Colette, 1993) also show decreasing biological efficiencies with increasing slaughter weight. Observed biological efficiency of the conventional system was lower than accelerated systems with 139 and 178 d on feed, and simulated efficiencies also showed a similar trend. Difference in observed biological efficiency between the accelerated system with 242 d on feed and the conventional system was not significant; simulated biological efficiencies for these two systems also suggest a similar result. Accelerated and conventional systems in the experiment of Dikeman et al. (1985b) ranked the same with respect to observed and simulated biological efficiencies for both small- and large-framed

Table 3. Simulated and observed biological efficiencies[a] from two experiments

Experiment and frame size	System[b]	Days on feed	Slaughter wt, kg	Biological efficiency: Observed	Biological efficiency: Simulated
Dikeman et al. (1985a)					
Small	Accelerated	139	439	54.4	52.8
Small	Accelerated	178	492	56.9	48.9
Small	Accelerated	242	554	50.1	45.5
Small	Conventional	174	591	53.4	45.6
Dikeman et al. (1985b)					
Small	Accelerated	140	430	50.9	50.2
Small	Conventional	116	531	42.9	47.2
Large	Accelerated	180	507	55.9	54.9
Large	Conventional	122	590	41.1	44.4

[a]Grams of BW gained per megacalorie of ME consumed during the experimental period.
[b]Data from Dikeman et al. (1985a) were from crossbred steers produced from mating 7/8 Simmental sires to crossbred dams (crosses of Continental and British breeds). In the conventional system steers were backgrounded for 110 d. Data from Dikeman et al. (1985b) were as follows: Small = Angus × Hereford steers. In the conventional system steers were backgrounded for 140 d then put on feed for 116 d; Large = crossbred steers produced from mating Simmental sires to either Chianina × Angus or Chianina × Hereford females. In the conventional system steers were backgrounded for 180 d then put on feed for 122 d.

breeds. In addition both observed and simulated difference in biological efficiency between accelerated and conventional systems was smaller for the small-framed breed than for the large-framed breed. Lewis et al. (1990) obtained similar rankings in biological efficiency as Dikeman et al. (1985b) for intensive and extensive production systems. These results suggest that the methods used to simulate biological efficiencies would give similar rankings for accelerated and conventional systems as those obtained by Dikeman et al. (1985b) and Lewis et al. (1990) for similar slaughter end points and growth patterns.

Estimates of maintenance requirements (Table 2) used to simulate the experiments of Dikeman et al. (1985a,b), were obtained from the GPE data. The method used to estimate these maintenance requirements assumed that kf was constant and maintenance requirements varied between biological types of steers. This assumption was also used by Lamb et al. (1992) to estimate biological efficiencies of different biological types of steers. The assumption that kf was variable and maintenance requirements were constant between biological types of steers was investigated by using a constant maintenance requirement of 133 Mcal of ME/kg $BW^{.75}$ to estimate kf for each biological type of steer in the GPE data. Simulated biological efficiencies for the experiment of Dikeman et al. (1985b) using this constant maintenance requirement and breed estimates of kf from the GPE data were 41.9 and 42.7 for small-framed steers in the accelerated and conventional systems, respectively, and 42.5 and 39.4 for large-framed steers in the accelerated and conventional systems, respectively. These results show similar biological efficiencies for small- and large-framed steers in the accelerated system, whereas observed results (Table 3) show that large-framed steers were more efficient than small-framed steers in this system. Steers gained BW at a fast rate in the accelerated system and kf has a greater impact on biological efficiency than maintenance requirements; hence, the large-framed steers that had a smaller kf value than the small-framed steers were at a greater disadvantage, compared with a higher maintenance requirement and a higher kf value. The overall results suggest that simulated efficiencies for the experiment by Dikeman et al. (1985b) would be closer to observed values with a constant kf value and variable maintenance requirements.

Simulated Biological Efficiencies

Simulated efficiencies of the 17 biological types of steers for each of the 18 production systems are shown in Tables 4 through 9. Differences in EBW and FFM efficiencies reflect differences in the proportion of fat and FFM in EBW gain, and also breed differences in dMEM75 and in daily empty-body gain relative to current EBW.

Constant Carcass Weight End Point. For the slaughter end point of 300-kg carcass weight, with a high finishing ADG (Table 4), biological efficiencies in terms of FFM gain were less than or equal to 53% of efficiencies in terms of EBW gain for some of the small-framed breeds such as the straightbred Angus, Hereford × Angus, and crossbred Jersey steers. Large-framed breeds such as crossbred Limousin, Charolais, and Chianina steers were leaner at slaughter, and efficiencies of FFM gain were approximately 60% or more of EBW efficiencies. Efficiencies of EBW and FFM gain were lowest for crossbred Jersey, Red Poll and Sahiwal steers and highest for crossbred Limousin, Charolais, Gelbvieh, and Maine-Anjou steers.

For the backgrounding system in which steers gained 200 kg at an ADG of .5 kg (System 1), all biological types achieved the slaughter end point (300 kg carcass) with fewer than 56 d on feed; hence, this system was not feasible for any of the genotypes. In the second backgrounding system, straightbred Hereford and crossbred Jersey and Red Poll steers achieved the desired carcass weight with at least 56 d on feed. These steers gained BW at a slower rate than other genotypes. Also in this system steers compensated less than steers in System 1, because they grew at a faster rate during backgrounding (.9 kg vs .5 kg). The same effect was observed in backgrounding Systems 3 and 4; however, steers were lighter when started on feed than in backgrounding Systems 1 and 2, and hence more genotypes achieved the desired carcass weight with at least 56 d on feed.

Biological efficiency in terms of EBW gain was greatest with System 9, for all genotypes. All steers within all systems were slaughtered at the same carcass weight, and in System 9, steers achieved this carcass weight at the youngest age. For the other systems, efficiencies in terms of EBW gain ranked highest to lowest in the order 7, 4, 2, 6, 3, 8, and 5. This ranking shows that systems with the highest (.9 kg), intermediate (.5 kg), and lowest (.25 kg) rate of gain in the backgrounding phase, ranked highest, intermediate, and lowest, respectively. Within rate-of-gain categories, backgrounding systems with the shortest duration ranked highest. Slower rates of gain and increased durations of backgrounding, result in older animals at slaughter and increased maintenance requirements to gain the same amount of EBW. The increase in maintenance requirements may be responsible for the decreased efficiency of the backgrounding systems.

Biological efficiency in terms of FFM gain tended to be more variable between breeds. In this case System 9 was the most efficient for large-framed steers, but for small-framed steers two or more of the backgrounding systems (7, 4, 2, 6, and 3) were more efficient than System 9. There was a greater increase in leanness in small-framed steers when backgrounded vs going directly into a finishing system at weaning, than in large-framed steers. It seems that the increased amount of FFM gained by small-framed

Table 4. Biological efficiencies[a] for 17 biological types of steers grown under nine postweaning backgrounding systems then finished at a high rate of gain and slaughtered at 300-kilogram carcass weight, for feasible production systems only

Biological type	Output, kg[b]	Production system 1	2	3	4	5	6	7	8	9
Hereford	EBW	—	46.2	41.5	48.0	36.6	44.7	49.1	39.8	49.7
	FFM	—	29.4	27.1	30.1	23.6	28.1	30.1	25.0	28.3
Angus	EBW	—	—	39.8	46.5	35.4	43.6	48.2	39.0	48.8
	FFM	—	—	25.4	28.3	22.5	26.8	28.7	24.0	26.2
Hereford × Angus	EBW	—	—	38.8	46.0	34.3	43.0	48.1	38.3	48.2
	FFM	—	—	25.0	28.3	22.0	26.6	29.0	23.7	25.9
Jersey ×	EBW	—	42.8	38.5	44.4	34.5	41.7	45.4	37.4	45.9
	FFM	—	25.3	23.8	26.1	21.2	24.8	26.2	22.4	24.7
South Devon ×	EBW	—	—	38.8	46.8	34.1	43.2	48.1	38.1	49.7
	FFM	—	—	25.9	29.9	22.5	27.5	30.0	24.4	28.2
Limousin ×	EBW	—	—	38.7	47.1	33.8	42.9	47.5	37.8	51.7
	FFM	—	—	26.7	31.4	23.0	28.3	29.1	24.9	32.7
Charolais ×	EBW	—	—	—	47.6	33.2	43.7	47.8	38.1	53.5
	FFM	—	—	—	32.1	22.8	29.0	30.6	25.2	33.3
Simmental ×	EBW	—	—	36.9	45.2	31.8	41.5	45.3	36.2	49.9
	FFM	—	—	25.4	30.0	21.5	27.2	28.9	23.7	30.6
Red Poll ×	EBW	—	41.2	36.2	42.6	32.1	39.7	43.7	35.4	44.2
	FFM	—	25.6	23.2	26.2	20.5	24.6	26.5	22.0	24.4
Brown Swiss ×	EBW	—	—	36.5	44.7	31.5	41.1	45.7	35.9	48.8
	FFM	—	—	24.8	29.3	21.1	26.6	28.9	23.2	29.1
Gelbvieh ×	EBW	—	—	—	46.0	32.1	42.1	46.7	36.8	50.0
	FFM	—	—	—	30.4	21.8	27.6	29.9	24.0	30.0
Maine Anjou ×	EBW	—	—	—	46.7	32.4	42.5	46.2	37.1	51.0
	FFM	—	—	—	31.5	22.3	28.4	29.9	24.8	31.5
Chianina ×	EBW	—	—	34.8	42.8	29.7	39.2	44.4	34.2	49.1
	FFM	—	—	24.5	29.1	20.5	26.2	28.2	22.8	32.4
Brahman ×	EBW	—	—	—	44.0	31.1	40.7	45.8	36.0	47.2
	FFM	—	—	—	28.6	21.1	26.6	29.3	23.5	27.2
Sahiwal ×	EBW	—	—	35.1	41.8	30.5	38.8	42.6	34.2	44.2
	FFM	—	—	22.7	25.8	19.6	24.0	25.8	21.2	25.2
Pinzgauer ×	EBW	—	—	38.4	45.9	33.6	42.6	47.1	37.5	48.4
	FFM	—	—	25.6	29.5	22.2	27.3	29.6	24.0	27.6
Tarentaise ×	EBW	—	—	36.4	44.0	31.6	40.5	45.2	35.6	47.3
	FFM	—	—	24.5	28.4	21.1	26.2	28.5	23.0	27.7

[a]Grams of empty body weight or fat-free matter gained/Mcal of ME consumed from weaning to slaughter.
[b]EBW is empty body weight gained from weaning to slaughter, FFM is fat-free matter gained from weaning to slaughter.

steers in backgrounding systems was enough to offset the increased maintenance requirements and resulted in some of these systems being more efficient than System 9. Compared with efficiency of EBW gain, backgrounding systems ranked similarly for efficiency of FFM gain, except that for some genotypes there was very little difference between Systems 7, 4, and 2.

Results for the slaughter end point of 300 kg carcass weight with a low finishing ADG are shown in Table 5. System 3 was feasible for all genotypes, and Systems 1 and 2 were feasible with more genotypes compared with the high ADG finishing system. This is a result of the slower growth rate in the finishing period, and thus steers had to be kept for a longer time on feed to achieve the desired carcass weight. Compared with the high ADG finishing system, efficiency in terms of EBW gain was between 3 to 4 g lower for all genotypes in System 9, and in the other systems it was approximately 1 to 3 g lower. This may be explained in part by the fact that in both finishing systems all breeds gained the same weight, but in the low finishing system steers were older when they achieved the desired carcass weight and hence had greater maintenance requirements. There was very little difference in efficiency of FFM gain between the two finishing systems when steers were finished directly after weaning (System 9). With some of the small-framed genotypes (Jersey and Red Poll crossbred steers) both EBW and FFM were gained more efficiently in System 4 than in 9. Backgrounding

Table 5. Biological efficiencies[a] for 17 biological types of steers grown under nine postweaning backgrounding systems then finished at a low rate of gain and slaughtered at 300-kilogram carcass weight, for feasible production systems only

Biological type	Output, kg[b]	Production system								
		1	2	3	4	5	6	7	8	9
Hereford	EBW	35.5	43.2	39.3	43.4	34.6	39.4	43.5	36.0	44.2
	FFM	24.4	28.1	26.0	27.7	22.7	23.8	26.2	23.0	27.9
Angus	EBW	—	41.9	38.3	42.9	33.6	39.4	42.4	36.0	43.5
	FFM	—	26.3	24.8	26.7	21.7	24.8	24.5	22.7	26.1
Hereford × Angus	EBW	—	41.5	37.6	42.5	32.7	39.2	42.0	35.5	43.3
	FFM	—	26.3	24.5	26.7	21.3	24.8	24.1	22.4	25.9
Jersey ×	EBW	33.4	40.4	36.4	40.8	32.6	37.5	40.2	34.5	40.4
	FFM	21.6	24.3	22.8	24.6	20.4	22.9	22.7	21.1	23.7
South Devon ×	EBW	—	42.3	37.3	43.1	32.8	39.5	43.2	35.6	45.0
	FFM	—	27.9	25.1	28.0	21.9	25.6	25.9	23.1	28.2
Limousin ×	EBW	—	42.4	37.2	43.4	32.1	39.5	44.4	34.5	46.2
	FFM	—	29.3	25.9	28.7	22.1	25.7	29.4	21.6	32.0
Charolais ×	EBW	—	—	37.1	44.2	31.9	40.1	45.4	35.9	48.7
	FFM	—	—	26.0	29.0	22.1	26.4	29.7	24.0	33.1
Simmental ×	EBW	—	41.3	35.9	41.5	30.6	37.9	42.4	34.3	45.3
	FFM	—	28.4	24.9	27.7	20.9	24.9	27.2	22.6	30.2
Red Poll ×	EBW	30.8	38.8	34.5	38.8	30.3	35.4	38.2	32.4	38.7
	FFM	20.8	24.5	22.5	24.5	19.7	22.5	22.2	20.6	23.6
Brown Swiss ×	EBW	—	40.4	35.2	40.7	30.3	37.7	41.7	33.9	44.1
	FFM	—	27.3	24.1	26.9	20.5	24.6	26.1	22.1	28.8
Gelbvieh ×	EBW	—	—	35.9	42.0	30.8	38.7	42.6	34.8	45.3
	FFM	—	—	24.8	28.0	21.1	25.6	27.0	23.0	29.8
Maine Anjou ×	EBW	—	—	36.5	42.5	30.9	38.2	43.5	34.7	46.5
	FFM	—	—	25.6	27.6	21.5	24.6	28.3	23.4	31.4
Chianina ×	EBW	—	39.0	33.5	40.4	28.3	36.5	41.3	31.5	43.9
	FFM	—	27.6	23.7	27.4	19.7	24.1	28.3	21.0	31.3
Brahman ×	EBW	—	—	34.6	39.7	29.6	37.7	40.4	33.7	42.3
	FFM	—	—	23.7	26.3	20.3	25.0	24.8	22.3	27.0
Sahiwal ×	EBW	—	38.0	33.6	38.4	29.0	35.1	38.2	31.7	38.8
	FFM	—	24.1	22.0	24.2	18.8	22.1	22.6	19.9	24.1
Pinzgauer ×	EBW	—	41.2	36.8	41.2	32.0	37.7	41.8	34.7	43.1
	FFM	—	27.2	24.8	27.0	21.5	24.6	25.4	22.7	27.4
Tarentaise ×	EBW	—	40.1	35.0	40.1	30.1	36.4	40.8	33.2	42.0
	FFM	—	26.7	23.8	26.3	20.4	23.8	25.2	21.7	27.2

[a]Grams of empty body weight or fat-free matter gained/Mcal of ME consumed from weaning to slaughter.
[b]EBW is empty body weight gained from weaning to slaughter, FFM is fat-free matter gained from weaning to slaughter.

systems with the highest rate of gain were the most efficient (Systems 7, 4, and 2), and backgrounding systems with the lowest rate of gain were the least efficient (Systems 8 and 5).

Results suggest that the most efficient system of producing EBW would be to put steers on a high-energy finishing diet directly after weaning. This strategy was also the most efficient for producing FFM, except for small-framed breeds that were more efficient when backgrounded after weaning. Within a particular genotype, backgrounding systems ranked the same for efficiency of EBW or FFM gain. However, within a particular system there was some reranking between genotypes. This is illustrated by comparing the Hereford and crossbred Chianina steers in backgrounding System 9 with the high finishing system. Hereford steers were slightly more efficient than crossbred Chianina steers in terms of EBW gain (49.7 vs 49.1) but were much less efficient in terms of FFM gain (28.3 vs 32.4). Similar results were obtained with Gelbvieh- and Chianina-sired steers. These results are probably due to the fact that both Hereford and crossbred Gelbvieh steers were fatter than crossbred Chianina steers at 300-kg carcass weight.

In both finishing systems, steers with high maintenance requirements (steers sired by some of the larger European breeds [Simmental, Brown Swiss, Chianina], Brahman, and Sahiwal) had the lowest biological efficiency in backgrounding systems with long durations, such as System 5. In this system

Table 6. Biological efficiencies[a] for 17 biological types of steers grown under nine postweaning backgrounding systems then finished at a high rate of gain and slaughtered at a small or greater degree of marbling, for feasible production systems only

Biological type	Output, kg[b]	Production system 1	2	3	4	5	6	7	8	9
Hereford	EBW	—	—	—	—	—	—	45.1	—	50.3
	FFM	—	—	—	—	—	—	26.7	—	28.7
Angus	EBW	36.0	44.3	39.1	46.7	32.6	42.9	49.7	36.9	52.7
	FFM	23.1	27.2	25.4	29.5	22.0	27.7	30.8	24.0	29.2
Hereford × Angus	EBW	35.6	43.6	39.2	46.2	34.8	42.9	49.4	38.0	52.4
	FFM	22.8	27.0	24.9	28.9	22.1	26.9	30.5	23.8	29.4
Jersey ×	EBW	34.4	42.6	37.0	44.9	31.5	41.3	47.6	35.6	49.7
	FFM	21.8	25.6	24.1	28.1	21.0	26.2	29.1	22.9	27.5
South Devon ×	EBW	35.9	44.2	39.4	46.9	34.7	43.2	49.0	37.7	54.1
	FFM	23.8	28.5	25.8	30.2	22.6	27.8	31.2	24.3	32.1
Limousin ×	EBW	—	—	—	—	35.9	—	45.7	37.6	45.5
	FFM	—	—	—	—	22.3	—	27.3	23.3	27.9
Charolais ×	EBW	36.9	44.9	40.2	47.2	35.3	43.9	48.5	38.5	56.5
	FFM	25.0	30.2	27.0	31.4	23.5	29.0	31.4	25.3	36.1
Simmental ×	EBW	35.2	42.5	38.6	44.3	34.1	41.8	45.0	37.3	51.1
	FFM	23.2	27.7	25.2	28.6	22.1	26.8	28.6	23.9	31.8
Red Poll ×	EBW	33.2	40.6	36.4	43.1	32.2	39.8	45.0	35.1	48.7
	FFM	21.4	25.3	23.2	27.0	20.5	25.1	28.0	22.1	28.0
Brown Swiss ×	EBW	34.6	42.2	38.1	44.1	33.5	41.4	45.5	36.7	50.7
	FFM	22.5	27.1	24.6	28.2	21.5	26.3	28.6	23.3	31.1
Gelbvieh ×	EBW	—	—	39.0	—	35.8	42.1	44.0	39.2	48.9
	FFM	—	—	24.4	—	22.2	26.0	27.1	24.1	29.0
Maine Anjou ×	EBW	—	—	—	—	36.3	41.2	45.2	39.4	51.6
	FFM	—	—	—	—	23.7	26.9	28.7	25.5	32.0
Chianina ×	EBW	—	—	—	—	—	—	41.4	36.8	42.3
	FFM	—	—	—	—	—	—	25.0	22.7	26.0
Brahman ×	EBW	—	—	—	—	34.1	—	—	37.6	47.4
	FFM	—	—	—	—	21.1	—	—	23.0	27.4
Sahiwal ×	EBW	33.2	39.0	35.8	39.3	32.5	37.8	40.4	35.0	43.1
	FFM	19.6	22.7	21.0	22.8	19.0	21.9	23.3	20.2	24.3
Pinzgauer ×	EBW	35.3	43.5	38.9	46.0	34.1	42.6	48.3	37.2	53.1
	FFM	23.5	28.2	25.5	29.8	22.4	27.6	30.9	24.1	31.6
Tarentaise ×	EBW	34.3	41.4	37.0	42.4	33.6	40.1	43.9	36.5	49.5
	FFM	21.9	26.0	23.5	26.6	21.2	25.1	27.2	22.8	29.5

[a]Grams of empty body weight or fat-free matter gained/Mcal of ME consumed from weaning to slaughter.
[b]EBW is empty body weight gained from weaning to slaughter, FFM is fat-free matter gained from weaning to slaughter.

steers had to maintain BW at low growth rates for 400 d, and when combined with a high maintenance requirement this tended to reduce overall biological efficiency.

Constant Marbling End Point. Results for the small or greater degree of marbling end point and a high ADG finishing system (Table 6) were similar to those for the 300-kg carcass weight end point. Steers gained EBW and FFM more efficiently in System 9 than in the backgrounding systems, except for Angus, Hereford × Angus, and crossbred Jersey steers, which tended to gain FFM slightly more efficiently in Systems 7 and 4. The most efficient backgrounding systems were those with the highest ADG (7, 4, and 2). Fewer systems were feasible for breeds that required a high level of carcass fatness to attain the desired marbling end point (Hereford, Limousin, Gelbvieh, Chianina, and Brahman crossbred steers). Steers of these breeds were either too old or too heavy when the desired marbling score was achieved.

Breeds that achieved a high degree of marbling at low levels of carcass fatness were younger at slaughter and gained EBW and FFM more efficiently (Angus, Hereford × Angus, and crossbred South Devon, Charolais, and Pinzgauer steers) than breeds that achieved the same degree of marbling at higher levels of carcass fatness (Hereford, crossbred Limousin, Chianina, and Sahiwal steers). Jersey crossbred steers also achieve very high degrees of marbling at low levels of carcass fatness, and the low efficiency of these steers is probably due to their slow growth rate. Production systems ranked the same within genotype

Table 7. Biological efficiencies[a] for 17 biological types of steers grown under nine postweaning backgrounding systems then finished at a low rate of gain and slaughtered at a small or greater degree of marbling, for feasible production systems only

Biological type	Output, kg[b]	Production system 1	2	3	4	5	6	7	8	9
Hereford	EBW	—	37.4	—	—	—	35.8	39.7	—	—
	FFM	—	22.5	—	—	—	21.3	23.5	—	—
Angus	EBW	34.2	42.1	37.0	44.4	31.1	39.6	45.1	34.7	47.9
	FFM	22.8	26.9	25.0	28.7	21.4	26.0	27.2	23.0	29.6
Hereford × Angus	EBW	34.5	41.5	37.8	42.7	33.2	39.1	44.8	35.5	46.5
	FFM	22.2	26.2	24.1	26.9	21.2	24.7	27.1	22.4	28.6
Jersey ×	EBW	33.1	40.8	34.9	42.9	30.3	38.1	43.1	33.5	44.7
	FFM	21.6	25.4	23.5	27.2	20.5	24.6	25.2	21.8	27.3
South Devon ×	EBW	34.8	42.2	37.7	43.1	33.5	39.6	45.5	35.6	47.3
	FFM	23.0	27.5	24.8	28.0	21.9	25.7	28.5	23.1	30.2
Limousin ×	EBW	—	—	—	—	—	—	—	34.8	—
	FFM	—	—	—	—	—	—	—	20.9	—
Charolais ×	EBW	35.3	41.6	37.6	44.3	33.9	40.1	45.5	36.7	45.4
	FFM	24.0	28.0	25.4	29.0	22.8	26.3	29.8	24.3	30.4
Simmental ×	EBW	33.8	39.0	37.0	40.0	32.6	37.5	41.9	35.1	42.3
	FFM	22.3	25.5	24.2	25.8	21.2	24.2	26.6	22.7	27.4
Red Poll ×	EBW	31.9	38.9	34.6	39.2	30.6	35.5	41.2	32.4	41.1
	FFM	20.6	24.6	22.2	24.8	19.6	22.5	25.1	20.6	25.6
Brown Swiss ×	EBW	33.2	39.3	36.2	38.9	31.8	37.5	41.7	34.5	42.1
	FFM	21.7	25.4	23.4	25.0	20.5	23.9	26.1	22.0	26.8
Gelbvieh ×	EBW	—	—	—	—	33.5	36.8	39.4	36.3	39.4
	FFM	—	—	—	—	20.9	22.9	24.1	22.5	24.4
Maine Anjou ×	EBW	—	—	—	41.4	—	38.1	40.8	35.8	39.8
	FFM	—	—	—	26.2	—	24.0	26.2	23.4	26.0
Chianina ×	EBW	—	—	—	—	—	33.8	—	—	—
	FFM	—	—	—	—	—	20.9	—	—	—
Brahman ×	EBW	—	—	—	—	—	—	37.7	—	35.2
	FFM	—	—	—	—	—	—	22.6	—	21.7
Sahiwal ×	EBW	31.1	34.5	33.1	33.9	30.2	32.9	35.4	31.7	34.0
	FFM	18.5	20.2	19.5	19.9	17.7	19.2	20.4	18.5	19.9
Pinzgauer ×	EBW	34.1	41.2	37.1	41.2	32.6	37.8	44.4	35.0	45.3
	FFM	22.7	27.0	24.5	26.9	21.5	24.7	28.0	22.9	29.1
Tarentaise ×	EBW	32.6	37.5	34.1	36.7	31.4	34.7	40.1	33.5	37.8
	FFM	20.9	23.7	21.7	23.2	19.9	21.9	24.6	21.1	23.8

[a]Grams of empty body weight or fat-free matter gained/Mcal of ME consumed from weaning to slaughter.
[b]EBW is empty body weight gained from weaning to slaughter, FFM is fat-free matter gained from weaning to slaughter.

for both measures of biological efficiency, but for some breeds there was some reranking within production system. For example, Angus steers gained EBW more efficiently but gained FFM less efficiently than Maine Anjou crossbred steers in System 9.

Results for the small or greater degree of marbling end point with a low rate of gain in the finishing period are shown in Table 7. Efficiencies of EBW and FFM were all lower than with the high ADG finishing system. Ranking of systems in order of decreasing biological efficiency was similar to the ranking obtained with the high ADG finishing system. Very few systems were feasible for Hereford, crossbred Limousin, and Chianina steers. Steers of these breeds were either too old or too heavy when the desired marbling end point was achieved.

Constant Carcass Fat End Point. Biological efficiencies for the 28% carcass fat end point with high and low ADG finishing systems are shown in Tables 8 and 9, respectively. With the high ADG finishing system (Table 8) all systems were feasible for the large-framed steers, whereas several of the systems were not feasible for the moderate- and small-framed steers. In systems that were not feasible for these moderate- and small-framed steers, the desired end point was achieved with less than 56 d on feed and(or) carcass weights less than 250 kg. All steers gained EBW and FFM more efficiently in System 9 than in the other backgrounding systems.

Several more breed × backgrounding system combinations achieved the 28% carcass fat end point with the low finishing system (Table 9) compared with the

Table 8. Biological efficiencies[a] for 17 biological types of steers grown under nine postweaning backgrounding systems then finished at a high rate of gain and slaughtered at a 28% carcass fat, for feasible production systems only

Biological type	Output, kg[b]	Production system 1	2	3	4	5	6	7	8	9
Hereford	EBW	—	—	41.3	48.6	36.1	44.8	51.1	39.0	—
	FFM	—	—	27.3	31.5	23.7	29.0	32.5	25.3	—
Angus	EBW	—	—	—	—	34.4	43.0	—	37.4	—
	FFM	—	—	—	—	22.5	27.6	—	24.1	—
Hereford × Angus	EBW	—	—	—	—	33.5	42.5	—	36.7	—
	FFM	—	—	—	—	21.9	27.3	—	23.7	—
Jersey ×	EBW	—	—	—	—	32.3	—	—	—	—
	FFM	—	—	—	—	21.2	—	—	—	—
South Devon ×	EBW	35.5	—	39.3	46.8	34.2	42.9	49.0	37.4	—
	FFM	23.8	—	25.9	30.3	22.5	27.8	31.2	24.2	—
Limousin ×	EBW	36.6	44.9	40.0	46.5	35.4	43.1	48.8	38.1	53.3
	FFM	24.7	29.9	26.6	30.6	23.4	28.3	30.9	24.9	34.1
Charolais ×	EBW	36.8	44.4	39.9	46.3	35.6	44.1	48.1	39.0	55.4
	FFM	24.9	29.7	26.7	30.7	23.7	28.9	30.9	25.5	35.0
Simmental ×	EBW	34.9	42.9	38.4	45.0	33.4	41.6	45.7	36.5	52.4
	FFM	23.5	28.5	25.5	29.5	22.1	27.2	29.3	23.8	33.0
Red Poll ×	EBW	—	—	35.7	42.8	31.1	39.3	—	34.1	—
	FFM	—	—	23.4	27.4	20.4	25.3	—	22.0	—
Brown Swiss ×	EBW	34.1	42.3	37.6	44.7	32.5	41.1	45.9	35.7	52.1
	FFM	22.8	27.8	24.8	29.1	21.3	26.7	29.3	23.1	32.5
Gelbvieh ×	EBW	35.3	43.4	38.8	45.6	33.8	42.3	47.2	37.4	52.9
	FFM	23.7	28.6	25.7	29.8	22.3	27.6	30.3	24.3	32.9
Maine Anjou ×	EBW	36.3	40.7	39.9	45.1	35.4	43.0	46.0	38.6	53.0
	FFM	24.7	27.5	26.9	30.1	23.6	28.5	29.8	25.4	33.3
Chianina ×	EBW	33.8	40.4	37.3	41.8	32.4	39.8	44.5	35.5	47.8
	FFM	22.9	27.1	24.9	27.8	21.6	26.2	28.4	23.3	31.1
Brahman ×	EBW	33.7	—	37.3	44.1	32.7	40.9	46.1	36.2	—
	FFM	22.6	—	24.6	28.6	21.6	26.6	29.5	23.5	—
Sahiwal ×	EBW	—	—	34.9	42.0	30.1	38.5	44.2	33.1	—
	FFM	—	—	22.7	26.8	19.5	24.6	27.8	21.2	—
Pinzgauer ×	EBW	35.2	—	38.8	46.2	34.0	42.6	48.2	37.2	—
	FFM	23.5	—	25.6	29.9	22.3	27.6	30.8	24.1	—
Tarentaise ×	EBW	33.6	—	37.2	44.2	32.3	40.6	45.9	35.5	—
	FFM	22.4	—	24.5	28.6	21.2	26.3	29.3	23.0	—

[a]Grams of empty body weight or fat-free matter gained/Mcal of ME consumed from weaning to slaughter.
[b]EBW is empty body weight gained from weaning to slaughter, FFM is fat-free matter gained from weaning to slaughter.

high finishing system (Table 8). Efficiencies of EBW and FFM gain for all genotypes in all backgrounding system were lower with the low ADG than with the high ADG finishing system. With the low ADG finishing system, steers were older and heavier than steers in the high finishing system at the same carcass fatness, which may account for the lower biological efficiencies. These differences in efficiency were greatest with System 9 and were considerably reduced in the other backgrounding Systems (1 through 8). These results suggest that if the objective is to produce carcasses with a reduced fat content, then the most efficient system would be one in which steers are put on a finishing diet with a high-energy density at weaning (System 9). In this system steers would achieve the desired level of carcass fatness at a younger age and at lighter weights than in other systems.

Summary. Postweaning biological efficiency in terms of BW gain is usually highest immediately after weaning and decreases as the postweaning period increases. This was illustrated by Melton and Colette (1993) with data on Hereford × Angus and crossbred Brahman and Pinzgauer steers and is a result of an increase in maintenance requirements, a decrease in growth rate, and an increase in the proportion of gain that is fat. Similar results were obtained in this study. Steers finished at a high rate of gain achieved the marbling end point at lighter carcass weights and were younger and more efficient in terms of EBW and FFM gain than steers finished at a low rate of gain. A similar result was also obtained for the carcass fat end

Table 9. Biological efficiencies[a] for 17 biological types of steers grown under nine postweaning backgrounding systems then finished at a low rate of gain and slaughtered at a 28% carcass fat, for feasible production systems only

Biological type	Output, kg[b]	Production system 1	2	3	4	5	6	7	8	9
Hereford	EBW	36.1	43.6	38.9	44.8	34.5	40.6	—	35.7	48.1
	FFM	24.2	28.7	25.8	29.2	22.8	25.9	—	23.3	31.1
Angus	EBW	—	—	38.0	44.4	32.9	39.9	—	35.4	—
	FFM	—	—	25.0	28.6	21.7	25.9	—	23.0	—
Hereford × Angus	EBW	33.6	—	37.3	43.6	32.5	39.5	—	34.9	—
	FFM	22.5	—	24.6	28.1	21.4	25.6	—	22.7	—
Jersey ×	EBW	—	—	35.7	—	31.3	—	—	33.6	—
	FFM	—	—	23.6	—	20.7	—	—	21.8	—
South Devon ×	EBW	34.5	42.3	37.7	43.4	33.2	39.7	45.6	35.3	47.8
	FFM	23.1	27.8	25.0	28.3	21.9	25.9	28.7	23.1	30.6
Limousin ×	EBW	35.1	40.8	37.7	42.8	33.4	39.4	43.3	34.2	40.8
	FFM	23.8	27.3	25.3	28.1	22.3	25.6	28.5	21.9	27.4
Charolais ×	EBW	35.1	41.0	36.3	43.8	34.1	40.0	44.8	36.9	44.4
	FFM	23.9	27.5	24.6	28.5	22.7	26.0	29.1	24.3	29.6
Simmental ×	EBW	33.7	40.6	37.0	40.9	32.1	37.7	42.8	34.6	43.9
	FFM	22.8	27.0	24.7	26.8	21.3	24.7	27.6	22.7	28.9
Red Poll ×	EBW	31.2	—	34.4	40.2	29.9	35.8	—	32.0	43.0
	FFM	20.8	—	22.6	25.9	19.7	23.2	—	20.8	27.3
Brown Swiss ×	EBW	32.9	40.6	36.0	40.2	31.3	37.6	42.5	34.0	43.8
	FFM	22.1	26.8	23.8	26.3	20.6	24.5	27.1	22.1	28.5
Gelbvieh ×	EBW	34.1	41.3	37.1	41.0	32.5	38.7	43.2	35.4	44.4
	FFM	23.0	27.4	24.7	27.0	21.6	25.4	27.6	23.2	28.9
Maine Anjou ×	EBW	—	36.1	35.1	42.4	33.7	38.2	43.0	36.2	43.1
	FFM	—	24.7	24.0	27.4	22.6	24.6	27.9	24.1	28.6
Chianina ×	EBW	32.2	36.9	34.9	38.9	30.7	36.5	38.0	32.6	38.0
	FFM	21.9	24.7	23.5	25.7	20.5	23.7	25.4	21.4	25.7
Brahman ×	EBW	32.7	39.8	35.7	38.8	31.3	37.6	42.0	34.3	43.0
	FFM	22.0	26.2	23.7	25.5	20.8	24.8	26.4	22.5	27.6
Sahiwal ×	EBW	30.3	—	33.7	39.1	28.9	35.2	40.7	31.3	40.8
	FFM	20.1	—	22.0	25.1	18.9	22.6	25.4	20.1	26.0
Pinzgauer ×	EBW	34.1	41.1	37.1	41.2	32.6	37.8	44.2	34.7	45.1
	FFM	22.8	27.0	24.6	27.0	21.5	24.7	27.8	22.7	29.0
Tarentaise ×	EBW	32.5	39.6	35.7	39.7	31.0	36.4	42.4	33.3	42.5
	FFM	21.8	26.0	23.6	26.0	20.5	23.7	26.8	21.7	27.6

[a]Grams of empty body weight or fat-free matter gained/Mcal of ME consumed from weaning to slaughter.
[b]EBW is empty body weight gained from weaning to slaughter, FFM is fat-free matter gained from weaning to slaughter.

point (Tables 8 and 9). However, when steers are grown for long durations at very slow rates then put on a finishing diet, it is possible that the overall biological efficiency may increase with increased carcass weight on the finishing diet. This is illustrated with results for crossbred Limousin in System 5, crossbred Gelbvieh, Brahman, and Sahiwal steers in Systems 5 and 8, and crossbred Chianina steers in System 8, finished at a high ADG and slaughtered at a minimum marbling end point (Table 6) or at 28% carcass fatness (Table 8). In this case, steers were heavier and more efficient in terms of EBW gain at the minimum marbling end point than at the 28% carcass fat end point.

Overall results show a decreasing rate of increase in biological efficiency as energy availability increased. This is illustrated with backgrounding Systems 5, 6, 7, and 9, in which rate of gain may be used as an index of energy availability. Biological efficiency increased at a decreasing rate from System 5 to 9 (Tables 4–9), and in some cases biological efficiency of FFM gain was maximum in System 7, then decreased in System 9 (Tables 4, 5, and 6). This relationship between energy availability and biological efficiency is probably partly a result of steers achieving the desired slaughter end points at younger ages, as energy availability increased.

Beef is marketed in a system in which it would be advantageous for carcasses to grade Choice and have a yield grade of 3 or lower. Yield grade is more related to FFM than to EBW. Results for all three slaughter end points show that production systems within genotype ranked the same for both efficiency of EBW and FFM gain. Conversely, some of the small-framed genotypes gained EBW more efficiently but gained FFM less efficiently than some of the large-framed genotypes. These results suggest that rankings on efficiency of FFM gain may be more advantageous within the present marketing system than rankings based on efficiency of EBW gain. This would also be true for a value-based marketing system.

Within production system, it is possible that ranking genotypes on the basis of biological efficiency may be similar to ranking on the basis of economic efficiency. However, for a specific genotype, the most biologically efficient production system may not be the same as the most economically efficient. Results show that systems in which steers were restricted in growth after weaning were generally less efficient than the system in which steers were put directly on a finishing diet after weaning. Low-energy feedstuffs are usually used in backgrounding systems, and steers on these diets require more ME to retain the same amount of energy as steers on a high-energy finishing diet. Also steers on low-energy diets are older at the same weight and use a greater proportion of total ME intake for maintenance compared to steers on high-energy diets. This combined effect of increased energy for maintenance and energy retention is responsible for the lower efficiency of backgrounding systems. In some cases low-energy feedstuffs may cost less per megacalorie of ME, and this could result in some backgrounding systems being more economically efficient than a system in which steers are put on a high-energy diet after weaning.

Implications

Considerable variation in postweaning biological efficiency exists between different genotypes of cattle and different postweaning production systems. In this study methods were developed to predict biological inputs and outputs and the relationships between these inputs and outputs for 17 biological types of steers grown under 18 postweaning production systems. These predicted biological inputs and outputs determine the biological efficiency of the system and may be used to identify the most efficient genotype for a particular production system. Producers can also use the predicted inputs and outputs along with present market costs and prices to compare different genotypes × production system combinations in terms of economic efficiency.

Literature Cited

Andersen, B. B. 1980. Feeding trials describing net requirements for maintenance as dependent on weight, feeding level, sex and genotype. Ann. Zootech. (Paris) 29:85.

Buckley, B. A. 1985. Relationship of body composition and fasting heat production in three biological types of growing beef heifers. Ph.D. Dissertation. Univ. of Nebraska, Lincoln.

Cundiff, L. V., R. M. Koch, and K. E. Gregory. 1984. Characterization of biological types of cattle–Cycle III. IV. Postweaning growth and feed efficiency. J. Anim. Sci. 58:312.

Cundiff, L. V., R. M. Koch, K. E. Gregory, and G. M. Smith. 1981. Characterization of biological types of cattle–Cycle II. IV. Postweaning growth and feed efficiency of steers. J. Anim. Sci. 53:332.

Dikeman, M. E., and J. D. Crouse. 1975. Chemical composition of carcasses from Hereford, Limousin and Simmental crossbred cattle as related to growth and meat palatability. J. Anim. Sci. 40:463.

Dikeman, M. E., A. D. Dayton, M. C. Hunt, C. L. Kastner, J. B. Axe, and H. J. Ilg. 1985a. Conventional versus accelerated beef production with carcass electrical stimulation. J. Anim. Sci. 61:573.

Dikeman, M. E., K. N. Nagele, S. M. Myers, R. R. Schalles, D. H. Kropf, C. L. Kastner, and F. A. Russo. 1985b. Accelerated versus conventional beef production and processing. J. Anim. Sci. 61:137.

Ferrell, C. L., and T. G. Jenkins. 1985. Cow type and the nutritional environment: Nutritional aspects. J. Anim. Sci. 61:725.

Fox, D. G., and J. R. Black. 1984. A system for predicting body composition and performance of growing cattle. J. Anim. Sci. 58:725.

Garrett, W. N. 1980. Energy utilization of growing cattle as determined in seventy-two comparative slaughter experiments. In: L. E. Mount (Ed.) Energy Metabolism. EAAP Publ. No. 26. p 3. Butterworths, London.

Garrett, W. N., and N. Hinman. 1969. Re-evaluation of the relationship between carcass density and body composition of beef steers. J. Anim. Sci. 28:1.

Gregory, K. E., L. V. Cundiff, G. M. Smith, D. B. Laster, and H. A. Fitzhugh, Jr. 1978. Characterization of biological types of cattle–Cycle II: I. Birth and weaning traits. J. Anim. Sci. 47:1022.

Gregory, K. E., G. M. Smith, L. V. Cundiff, R. M. Koch, and D. B. Laster. 1979. Characterization of biological types of cattle–Cycle III: I. Birth and weaning traits. J. Anim. Sci. 48:271.

Keele, J. W., C. B. Williams, and G. L. Bennett. 1992. A computer model to predict the effects of level of nutrition on composition of empty body gain in beef cattle: I. Theory and development. J. Anim. Sci. 70:841.

Lamb, M. A., M. W. Tess, and O. W. Robison. 1992. Evaluation of mating systems involving five breeds for integrated beef production systems: II. Feedlot segment. J. Anim. Sci. 70:700.

Lewis, J. M., T. J. Klopfenstein, R. A. Stock, and M. K. Nielsen. 1990. Evaluation of intensive vs extensive systems of beef production and the effect of level of beef cow milk production on postweaning performance. J. Anim. Sci. 68:2517.

Melton, B. E., and W. A. Colette. 1993. Potential shortcomings of output:input ratios as indicators of economic efficiency in commercial beef breed evaluations. J. Anim. Sci. 71:579.

Miller, R. K., H. R. Cross, J. D. Crouse, and J. D. Tatum. 1987. The influence of diet and time on feed on carcass traits and quality. Meat Sci. 19:303.

Montaño-Bermudez, M., and M. K. Nielsen. 1990. Biological efficiency to weaning and to slaughter of crossbred beef cattle with different genetic potential for milk. J. Anim. Sci. 68:2297.

Nehring, K., and G.F.W. Haenlein. 1973. Feed evaluation and ration calculation based on net energy$_{fat}$. J. Anim. Sci. 36:949.

Smith, G. M., J. D. Crouse, R. W. Mandigo, and K. L. Neer. 1977. Influence of feeding regime and biological type on growth, composition and palatability of steers. J. Anim. Sci. 45:236.

Smith, G. M., D. B. Laster, L. V. Cundiff, and K. E. Gregory. 1976a. Characterization of biological types of cattle II. Postweaning growth and feed efficiency of steers. J. Anim. Sci. 43:37.

Smith, G. M., D. B. Laster, and K. E. Gregory. 1976b. Characterization of biological types of cattle I. Dystocia and preweaning growth. J. Anim. Sci. 43:27.

Williams, C. B., G. L. Bennett, and J. W. Keele. 1995a. Simulated influence of postweaning production system on performance of different biological types of cattle: I. Estimation of model parameters. J. Anim. Sci. 73:665.

Williams, C. B., G. L. Bennett, and J. W. Keele. 1995b. Simulated influence of postweaning production system on performance of different biological types of cattle: II. Carcass composition, retail product, and quality. J. Anim. Sci. 73:674.